

National Aeronautics and
Space Administration



ARSET

Applied Remote Sensing Training

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Current and Future Satellite Capabilities for Air Quality Monitoring: An Overview

Pawan Gupta

Satellite Remote Sensing of Air Quality: Data, Tools, and Applications

Tuesday, May 23, 2017 – Friday, May 26, 2017

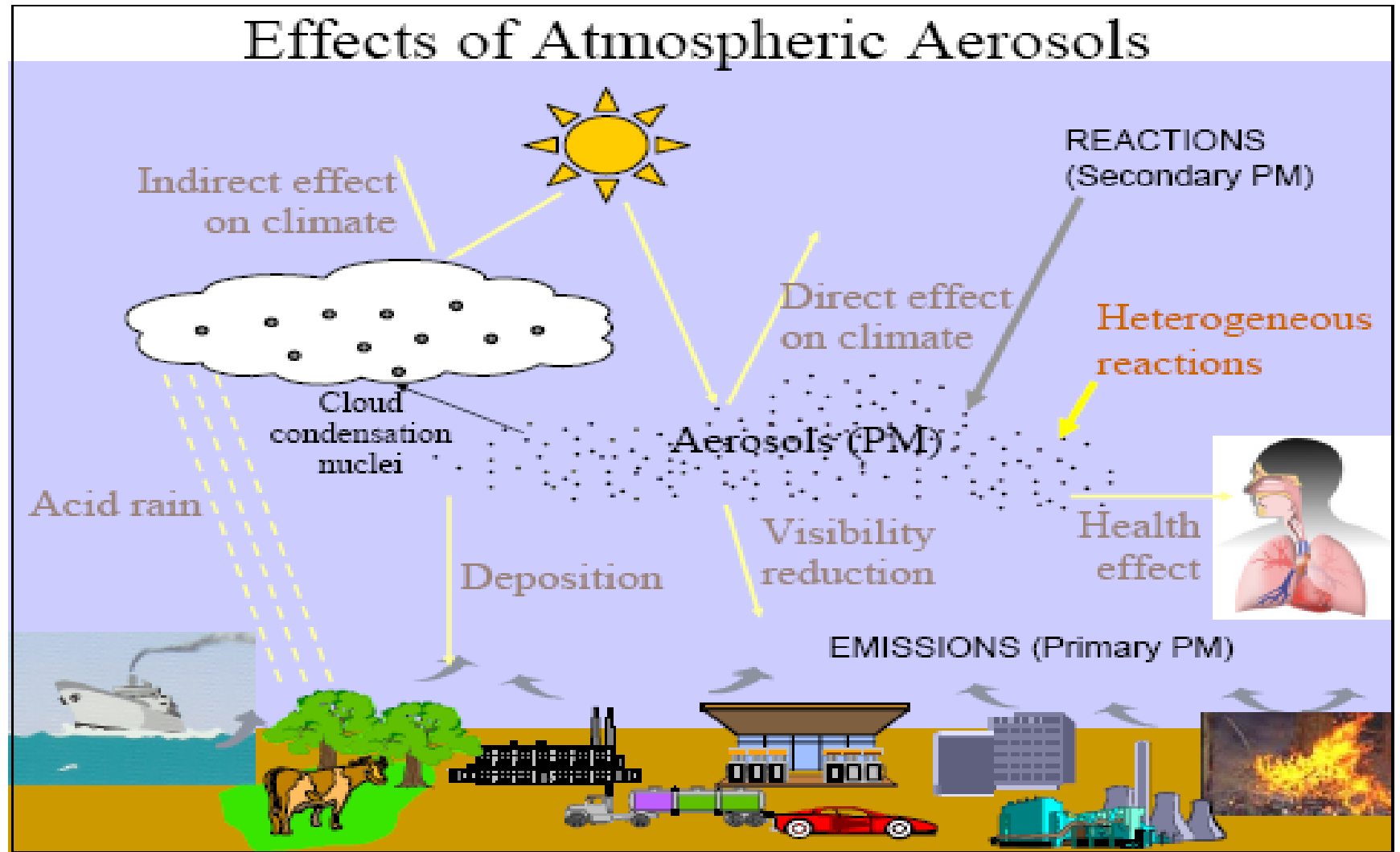
Indian Institute of Tropical Meteorology, Pune, India

Learning Objectives

By the end of this presentation, you will be able to:

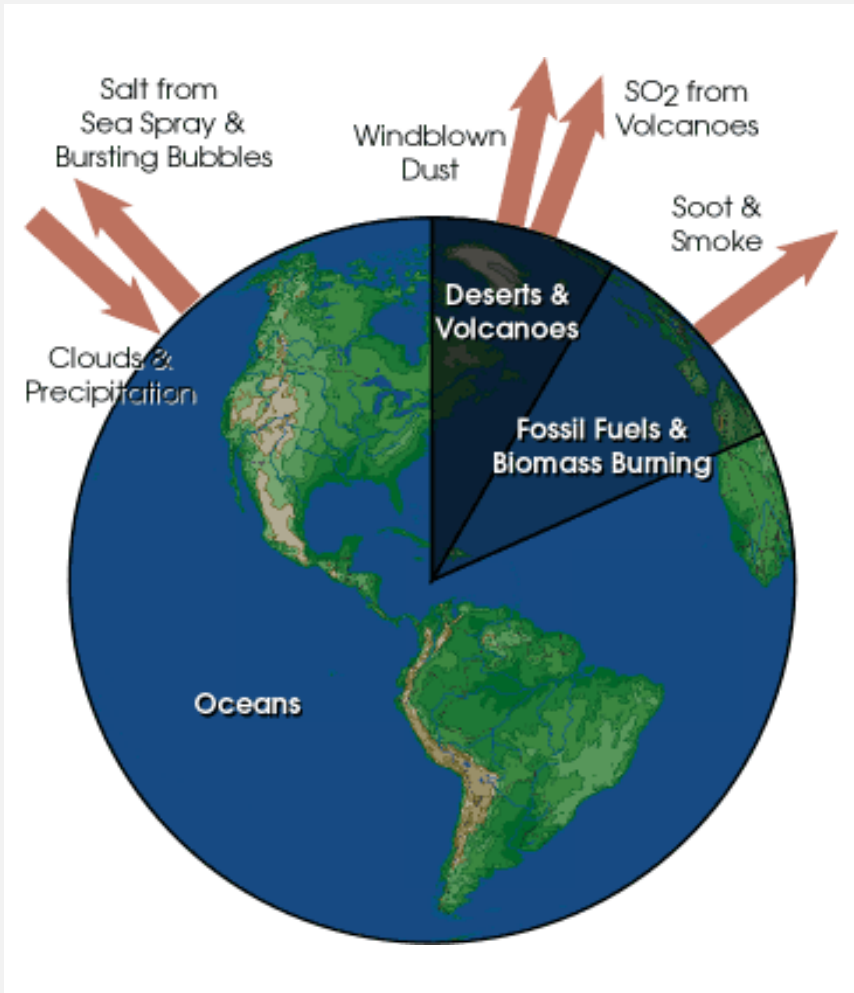
- describe existing satellite capabilities for global air quality monitoring
- identify upcoming and future satellite missions for air quality monitoring

Motivation: Tiny, but Potent

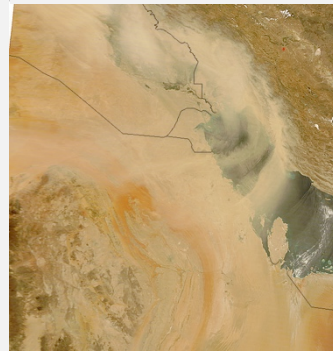


Pollution Sources

Atmospheric aerosols are highly variable in space and time



Dust



Fossil Fuels & Biomass Burning



Volcanoes

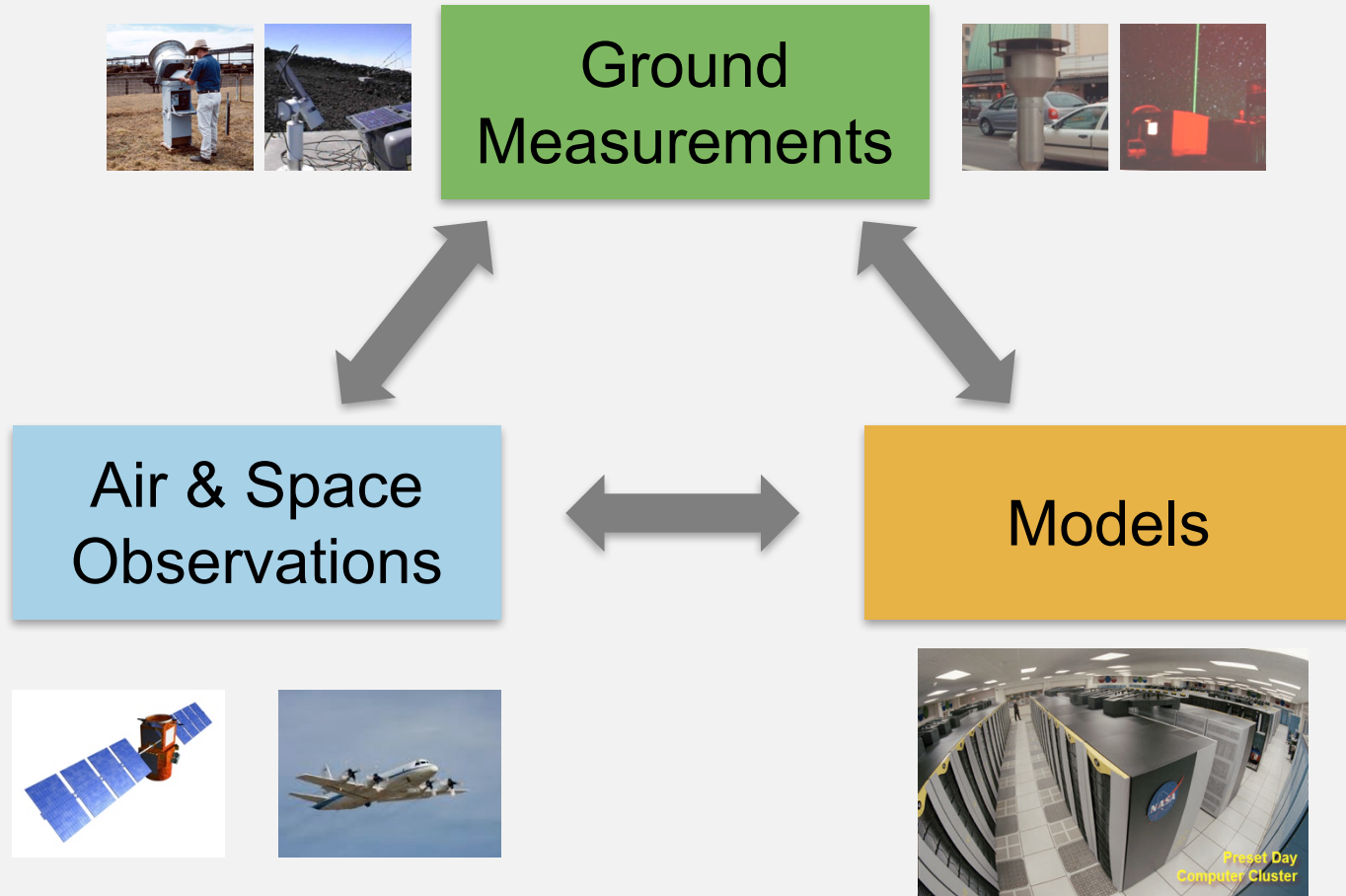


Soot & Smoke

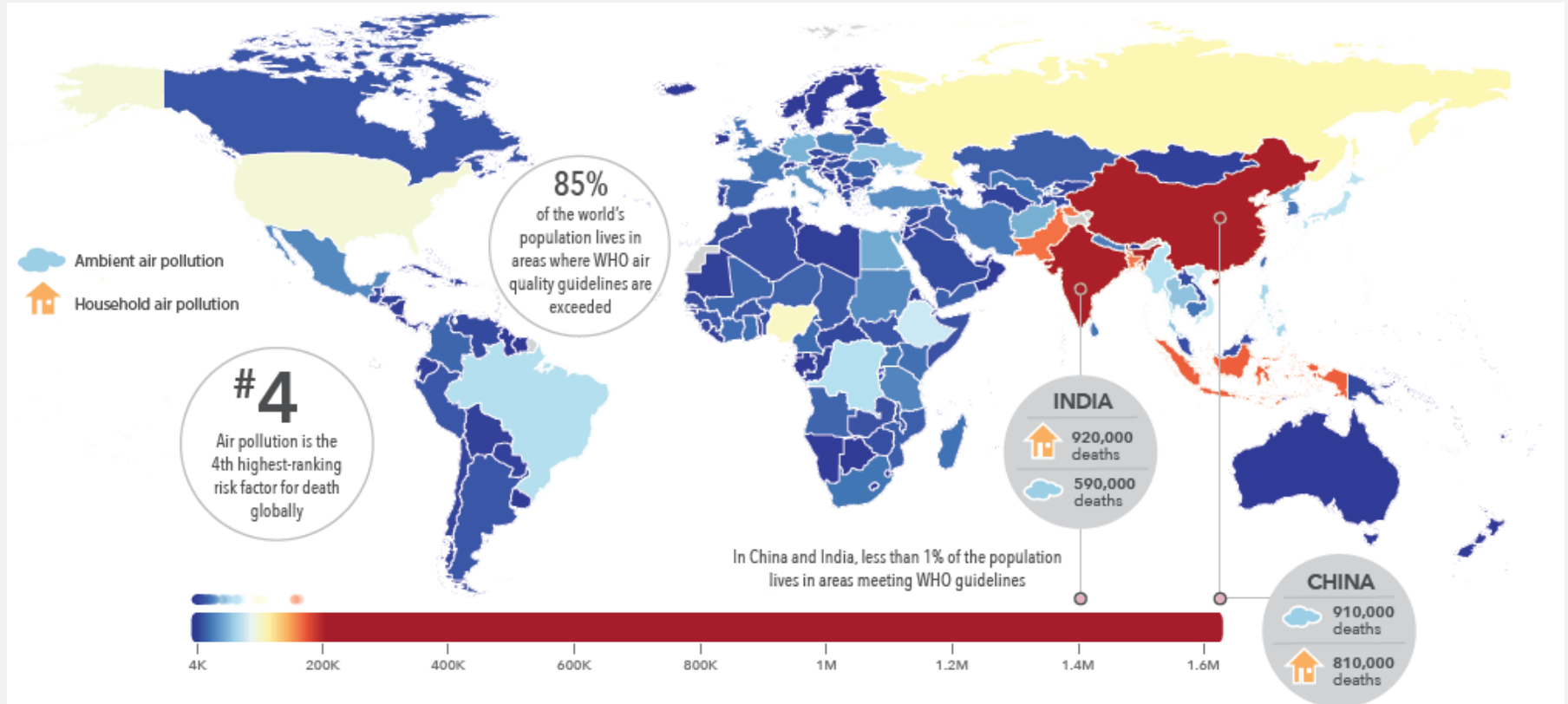
Traditional Air Quality Monitoring



Air Pollution Monitoring



Global Burden of Air Pollution



- Air pollution was responsible for 5.5 million deaths in 2013
- Satellite data can help quantify the impact on human health

Image Credit: <http://thelancet.com/gbd/2013>

UN Sustainable Development Goals (SDGs)

Transforming Our World: The 2030 Agenda for Sustainable Development



Text adapted from "[Transforming our world: the 2030 Agenda for Sustainable Development](#)"

- A plan of action for people, planet, and prosperity
- All countries and all stakeholders, acting in collaborative partnership, will implement this plan
- 17 SDGs and 169 targets under this agenda
- Balance the three dimensions of sustainable development:
 - economic, social, and **environmental**

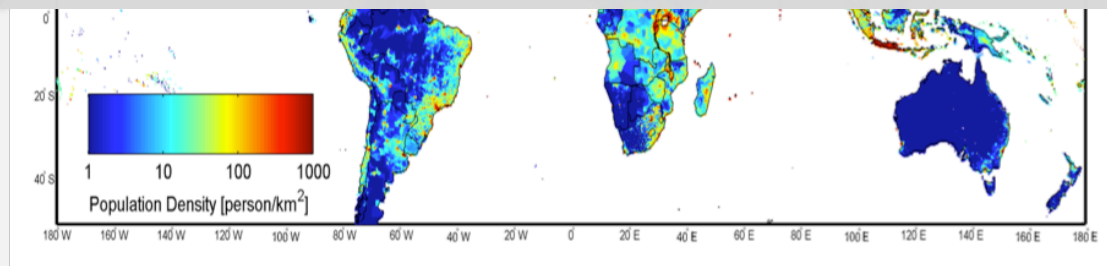
A satellite image of Earth showing a mix of land and water. The land is brown and green, with some snow-capped mountains. The water is dark blue. A semi-transparent grey rectangular box is overlaid on the image, containing the text "Why use satellite data?".

Why use satellite data?

Global Status of PM_{2.5} Monitoring

- Many countries do not have PM_{2.5} mass measurements
- Spatial distribution of air pollution from existing ground network does not support high population density
- 2,400 out of 3,100 counties in the U.S. (31% of the total population) have no PM monitoring
- Surface measurements are not cost effective
- How about using remote sensing satellites?

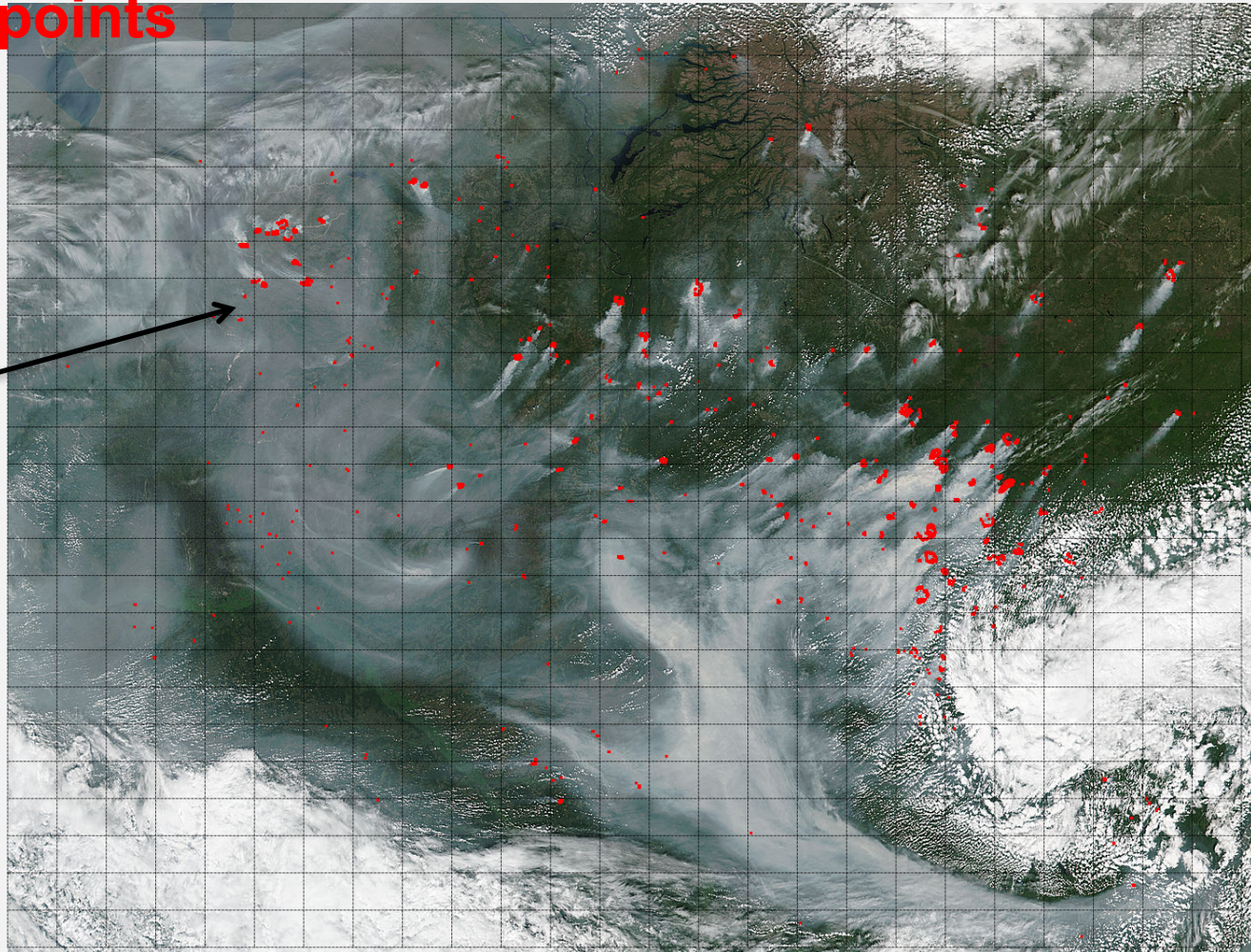
Density



“A picture is worth a thousand words”

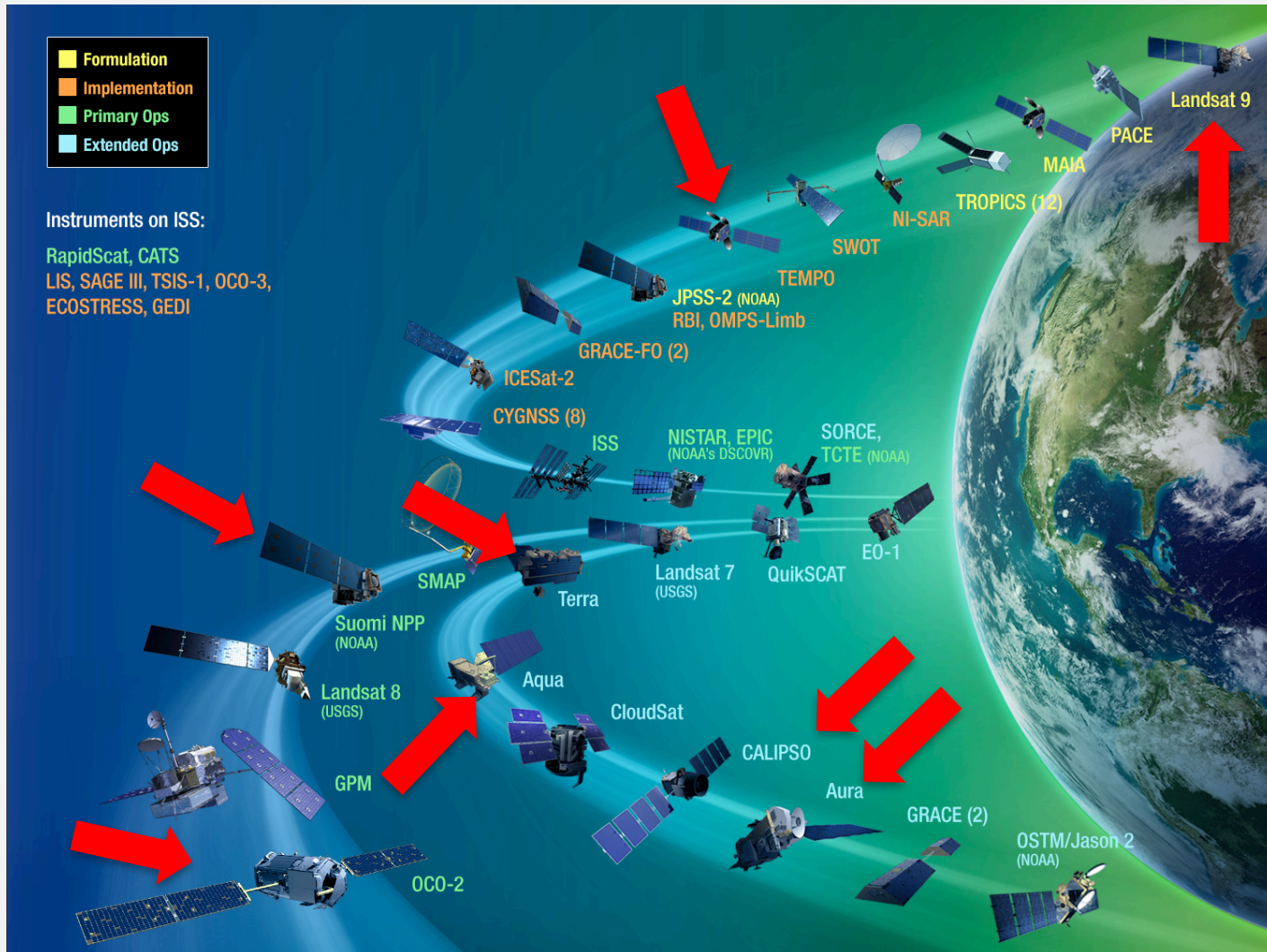
A satellite picture is worth a millions of data points

A Geo-
Physical
|
Number



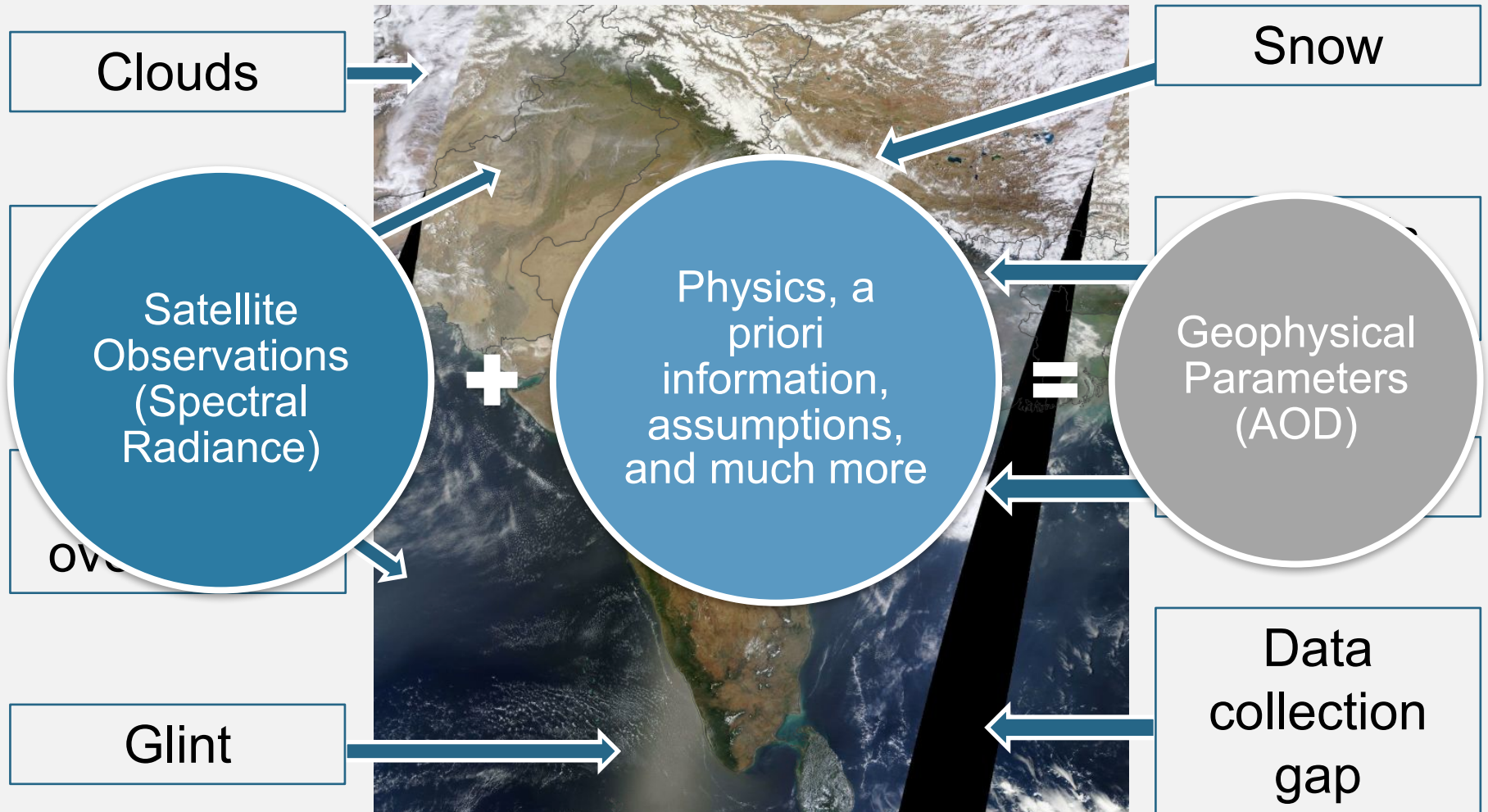
NASA Earth Science

Current and Upcoming Missions



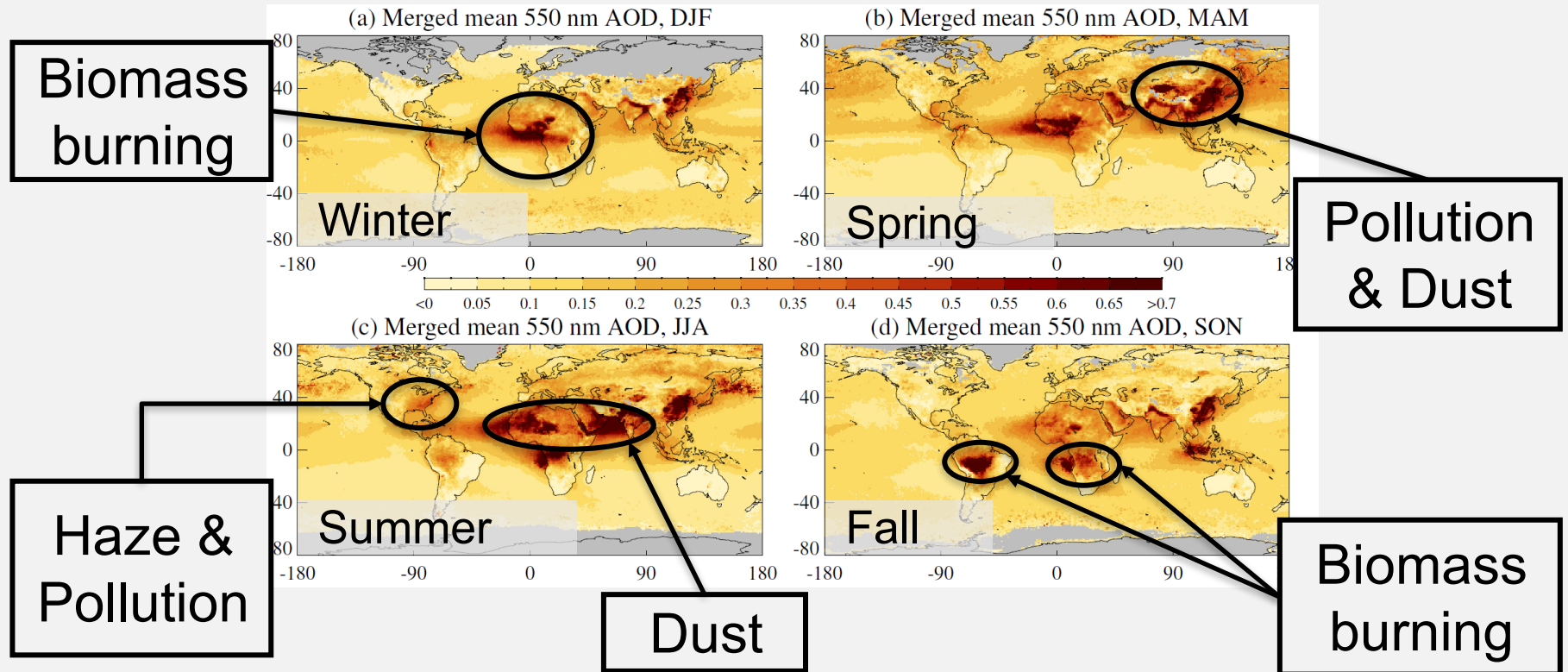
What can we learn from true color imagery?

MODIS Terra Image, April 19, 2013



Aerosols from Satellites

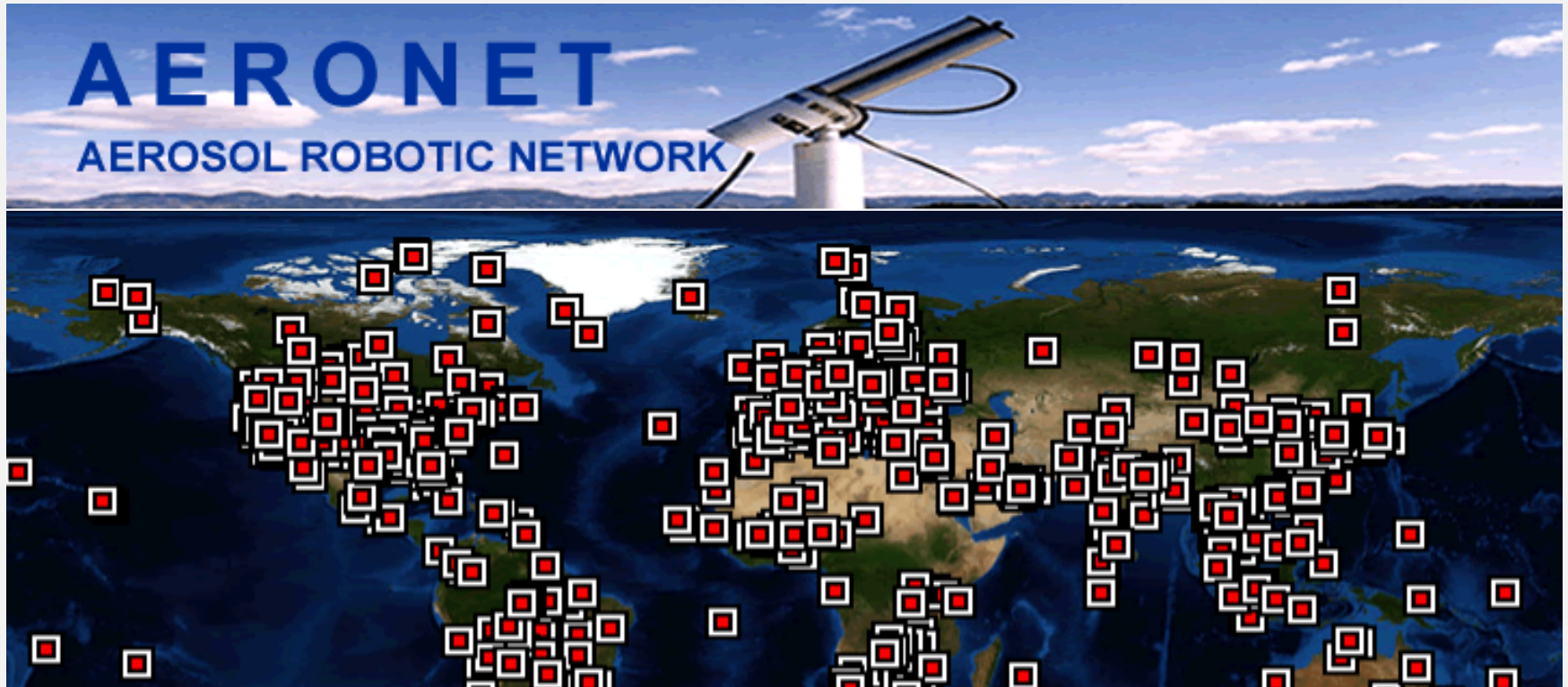
Aerosol Optical Thickness (MODIS Aqua)



Several satellites provide state-of-the-art aerosol measurements globally, on a daily basis

AERONET

<http://aeronet.gsfc.nasa.gov/>

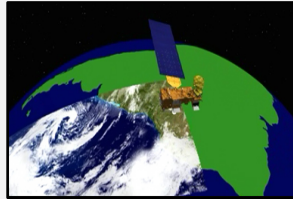


AERONET measurements of aerosol optical depth are considered ground truth and are used to validate satellite aerosol retrievals

A satellite image of the Arctic region, showing landmasses like Greenland, Iceland, and parts of Europe and North America, surrounded by the Arctic Ocean. A large, semi-transparent grey rectangular box is overlaid on the center of the image, covering most of the Arctic Ocean and parts of the surrounding land. The word "Applications" is written in black text in the bottom-left corner of this grey box, with a horizontal line underneath it.

Applications

Satellite vs. Ground Observation

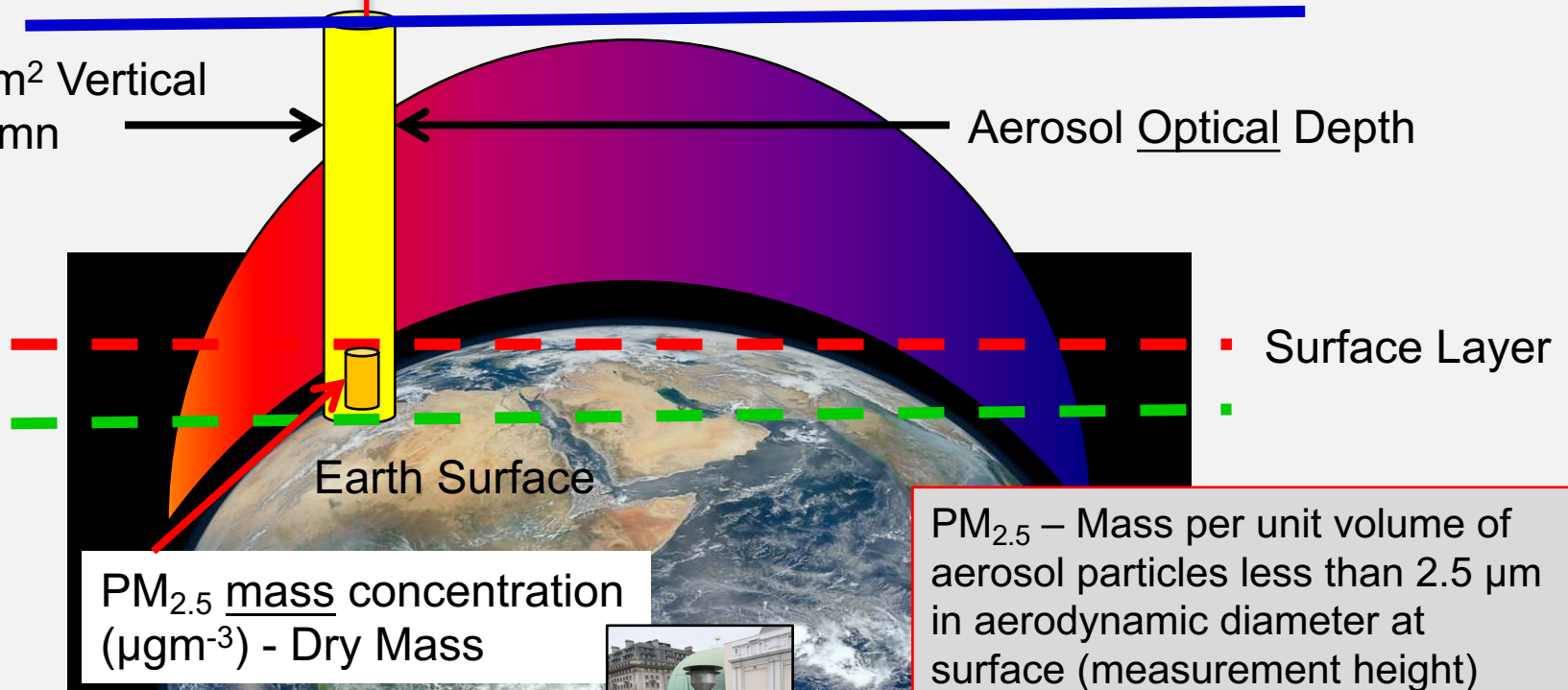


AOD – Column integrated value (top of the atmosphere to surface) - Optical measurement of aerosol loading – unitless. AOD is function of shape, size, type and number concentration of aerosols

Top of the Atmosphere

10 km² Vertical Column

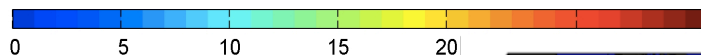
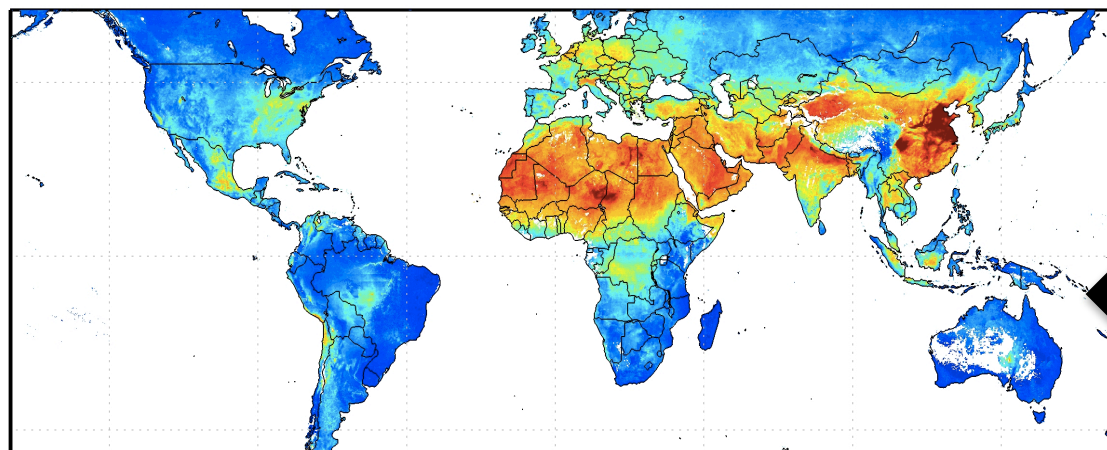
Aerosol Optical Depth



PM_{2.5} mass concentration
(μgm^{-3}) - Dry Mass

PM_{2.5} – Mass per unit volume of aerosol particles less than 2.5 μm in aerodynamic diameter at surface (measurement height) level

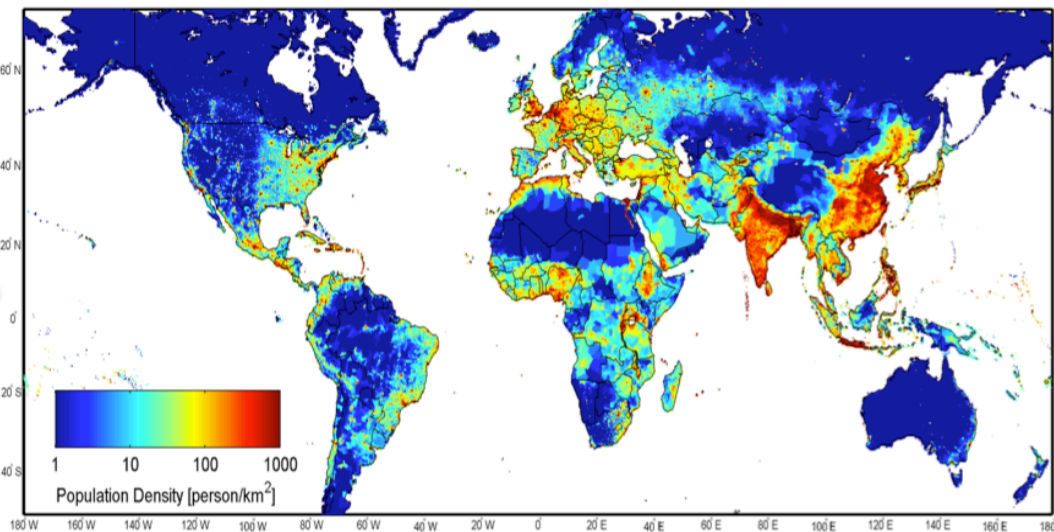
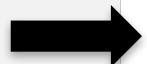
Global Status of PM_{2.5} Monitoring: Future View



Satellite-Derived PM_{2.5}

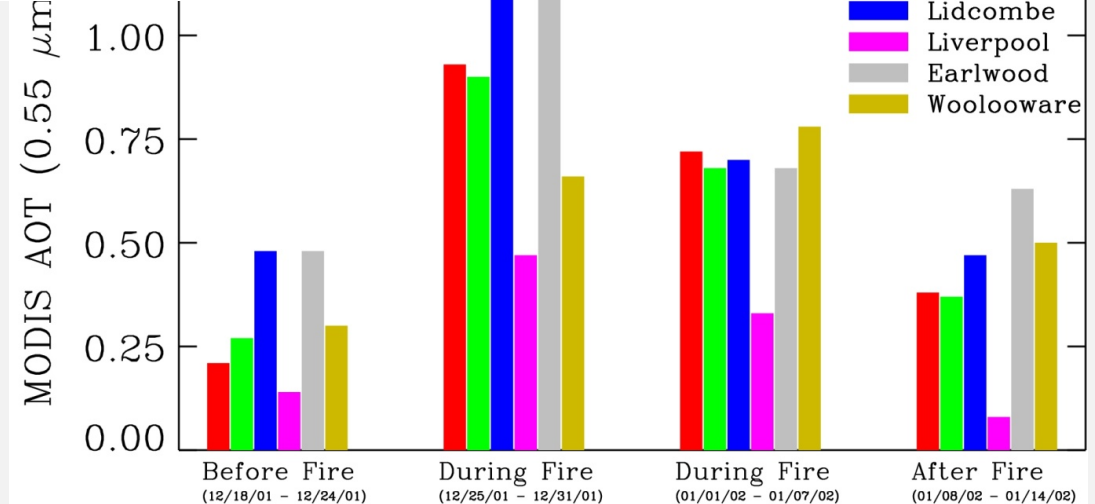
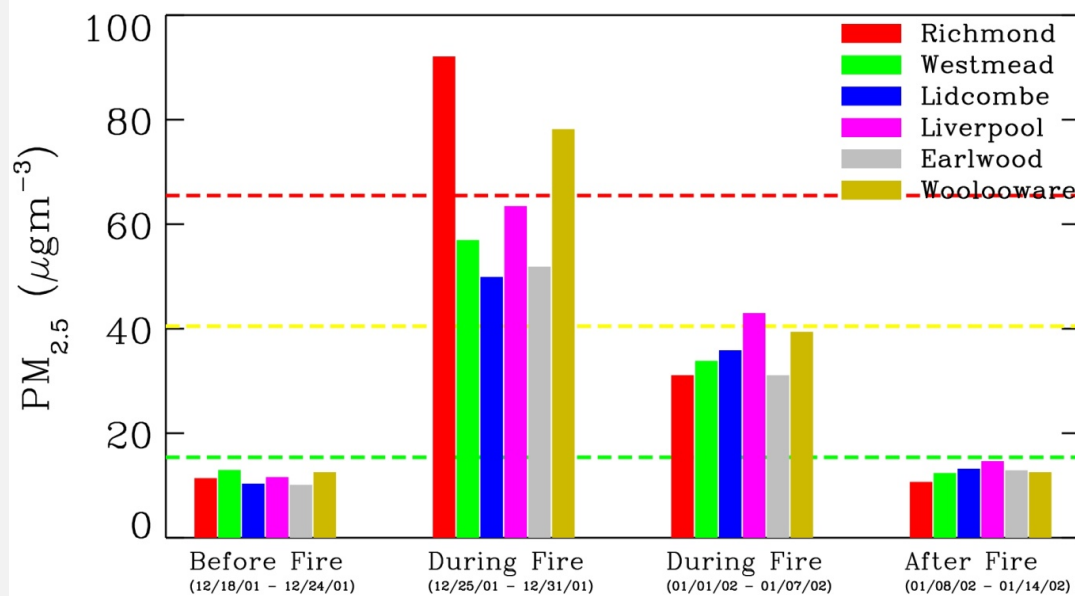
van Donkelaar et al., 2010

Population
Density



Satellite
Estimated PM_{2.5}

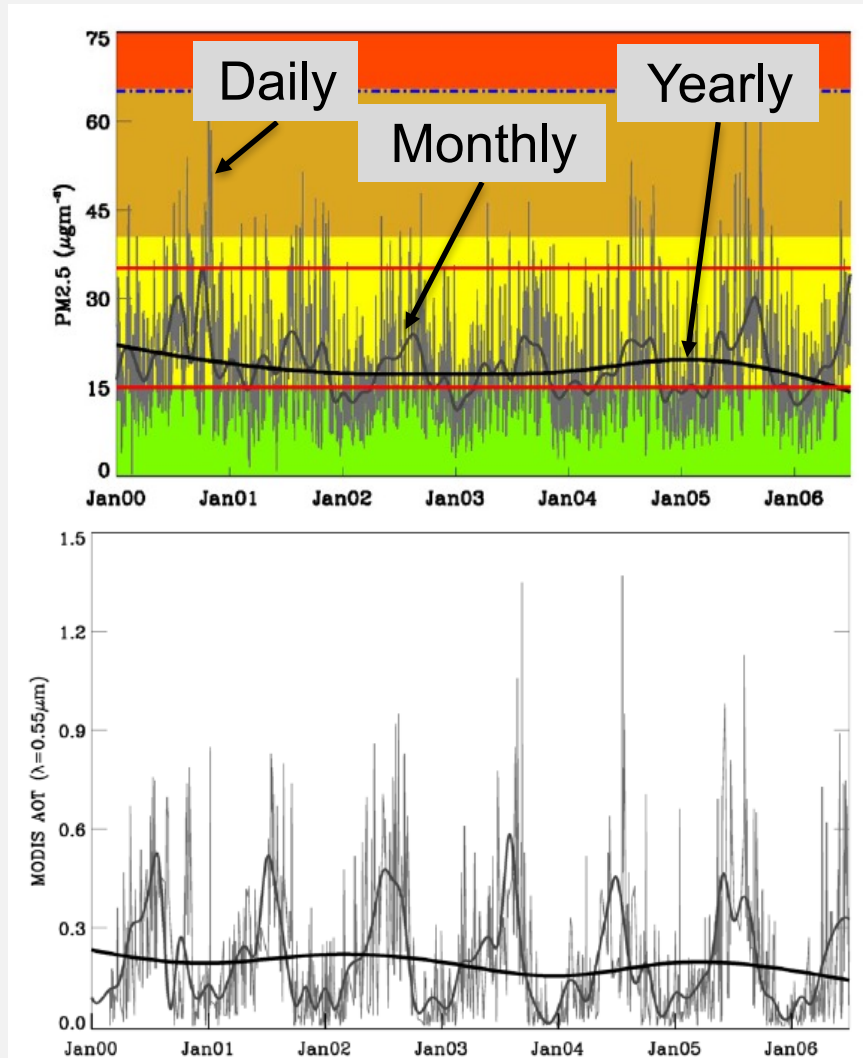
Application of Satellite Observations: Bushfires in Sydney, Australia



Credit: Gupta and Christopher, 2007

Air Quality Trends

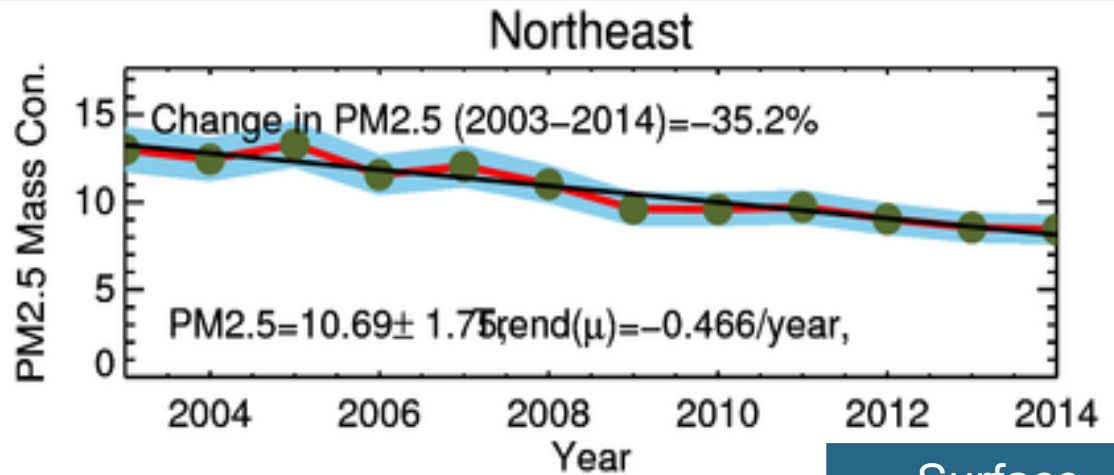
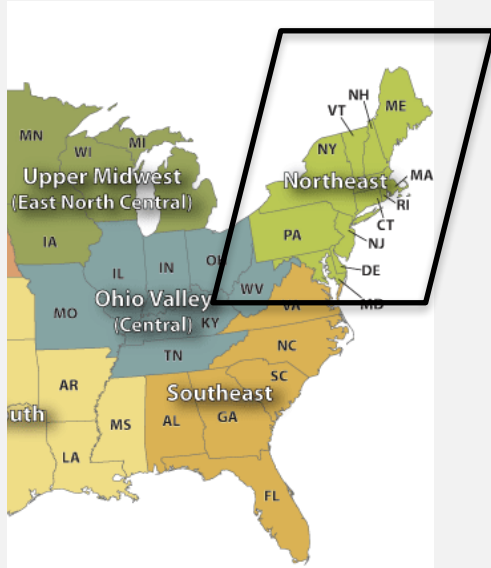
Birmingham, Alabama



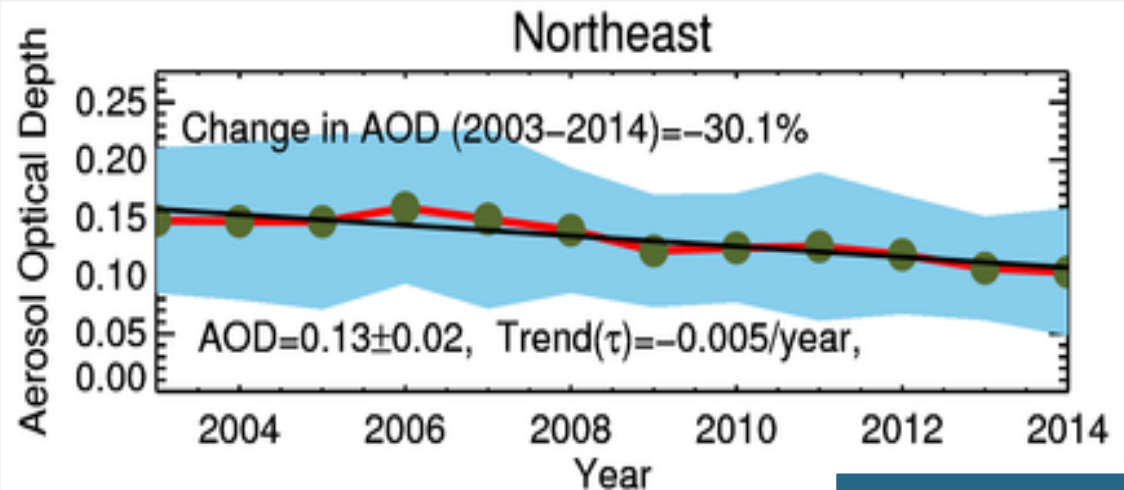
- A decreasing trend in annual PM_{2.5} was noted with the almost 22% reduction in PM_{2.5} mass concentration observed in 2006 compared to 2002
- MODIS-Terra Collection 5, Level 2, 10 km² AOTs for 2000-2006

Source: Gupta and Christopher, 2007

Measurements: Surface vs. Satellite

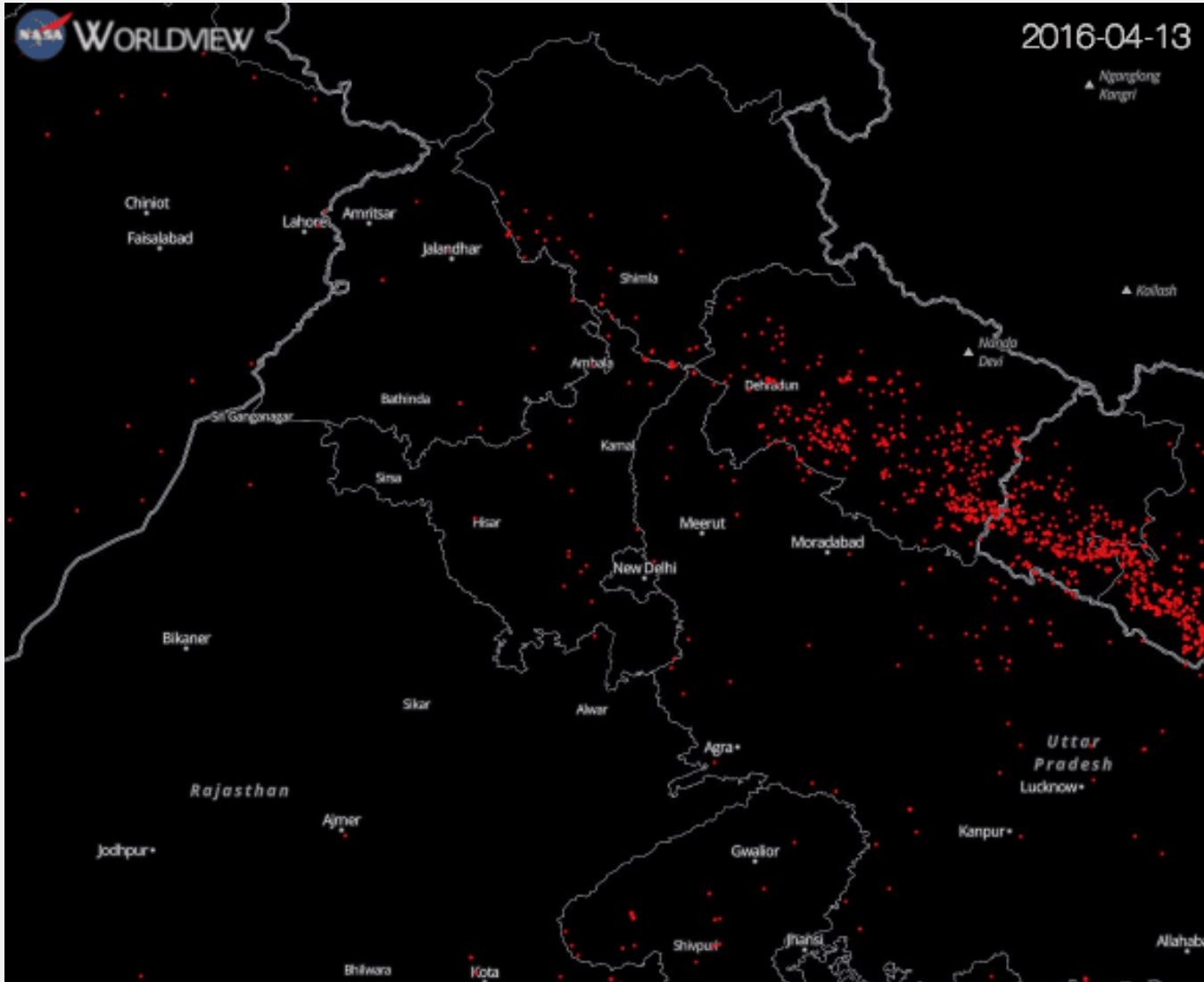


Surface



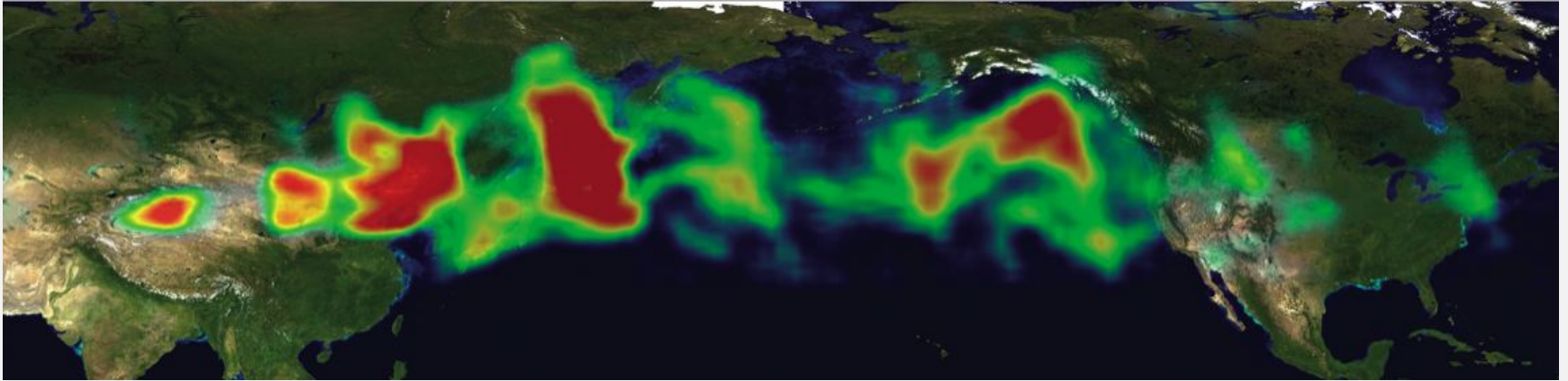
Satellite

Fire Detection and Monitoring

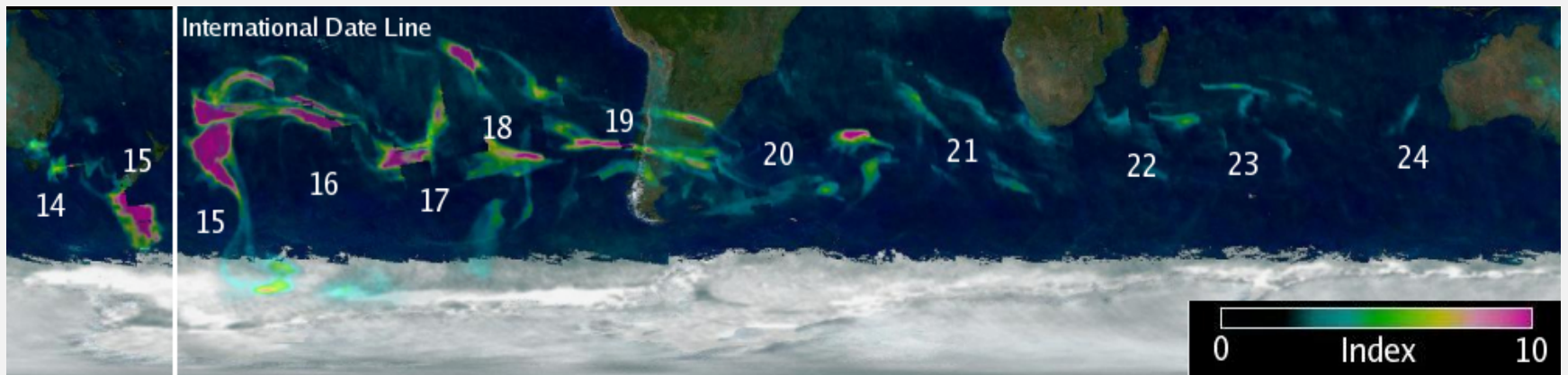


Long Range Transport

Dust from Mongolian Deserts Reaches the U.S.

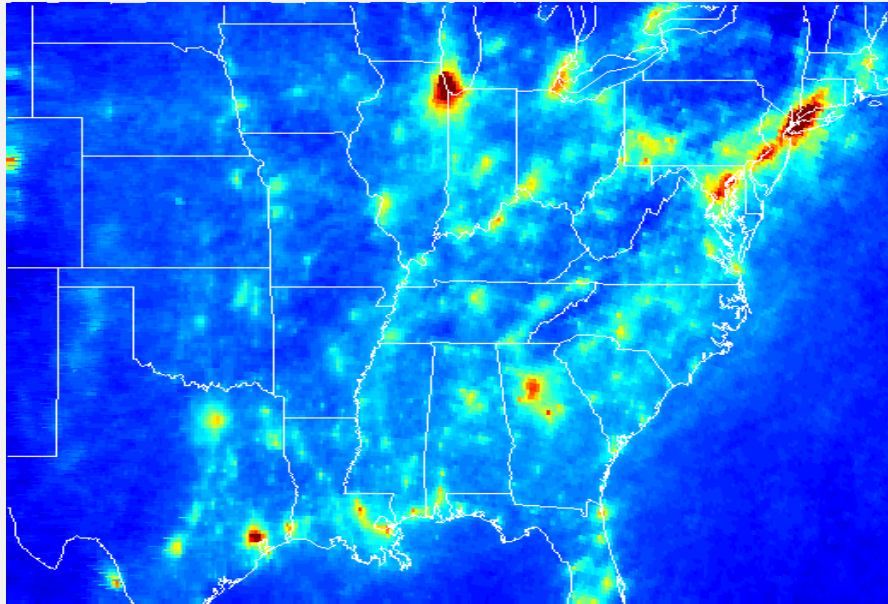


Smoke Travels Around the World in 11 Days

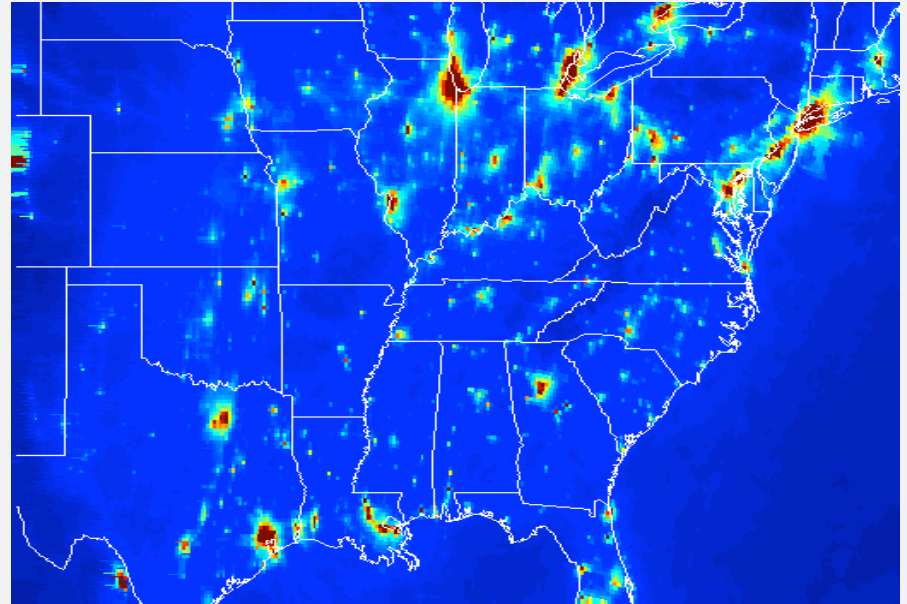


Model-Satellite Intercomparison

CMAQ Model NO₂

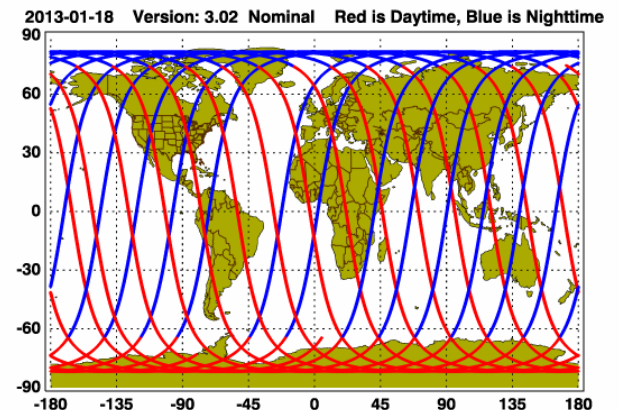
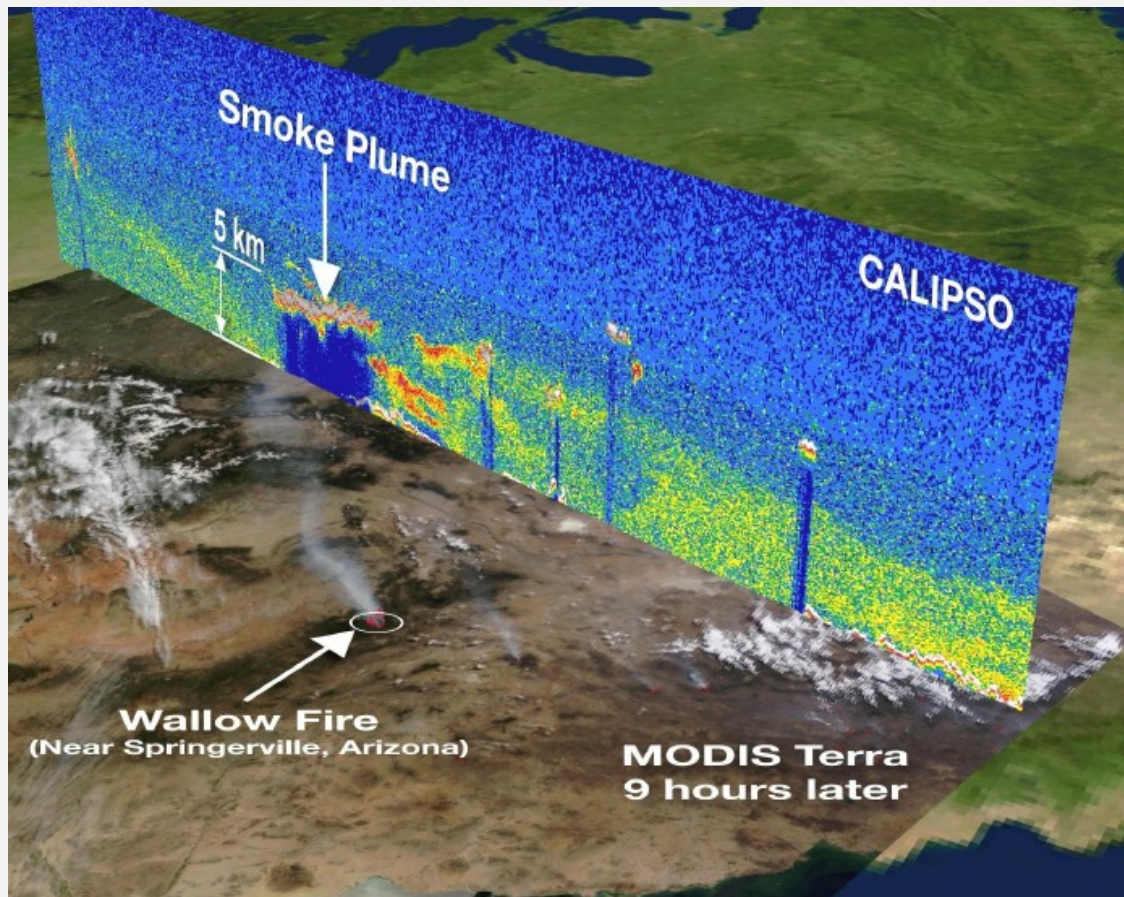


OMI NO₂



Vertical Profiles of Aerosols

CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations

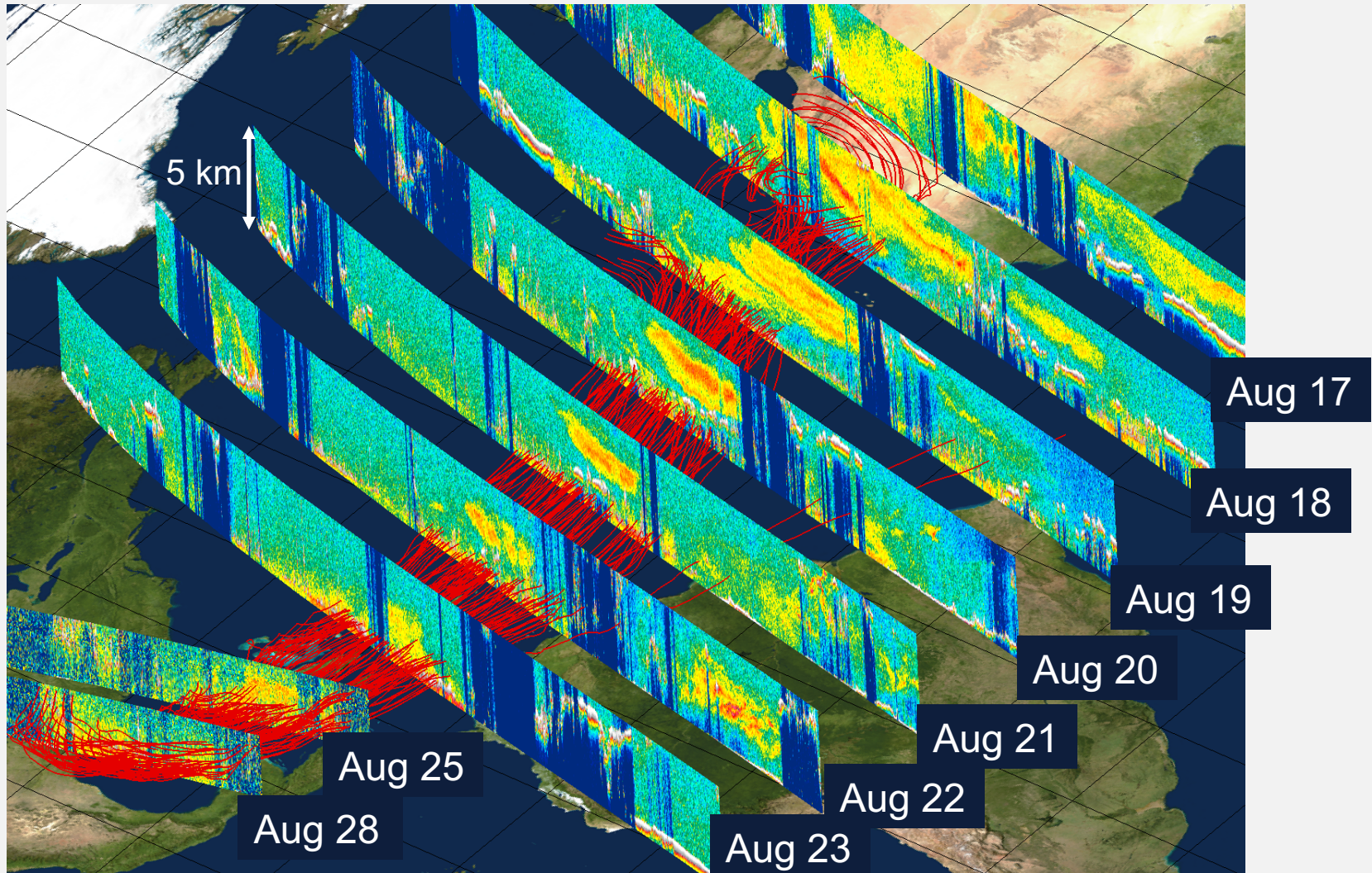


CALIPSO Browse Images

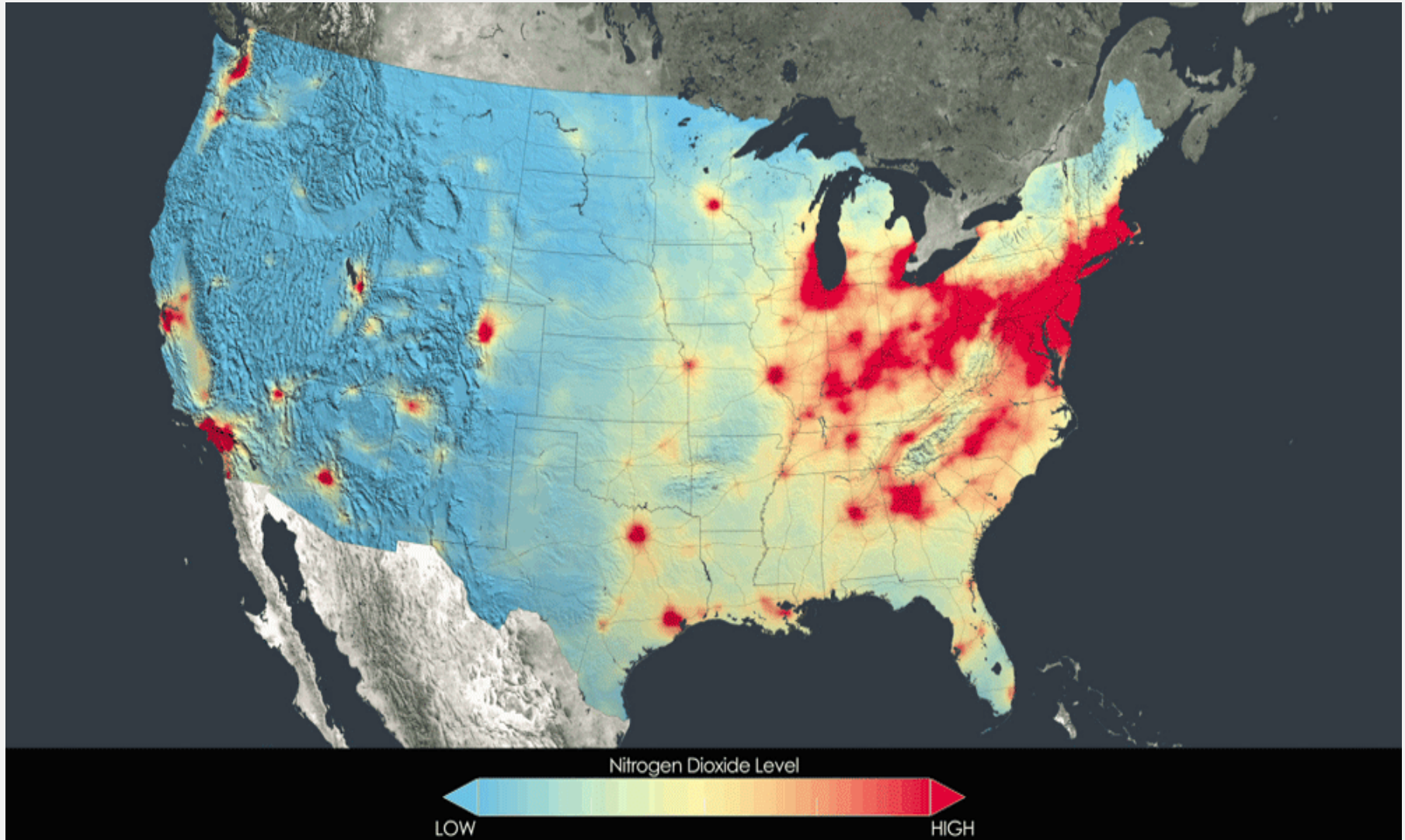
<http://www-calipso.larc.nasa.gov/products/lidar/browse/images/production/>

Example of CALIPSO Data

Major Saharan Dust Transport Event: Aug 17-28

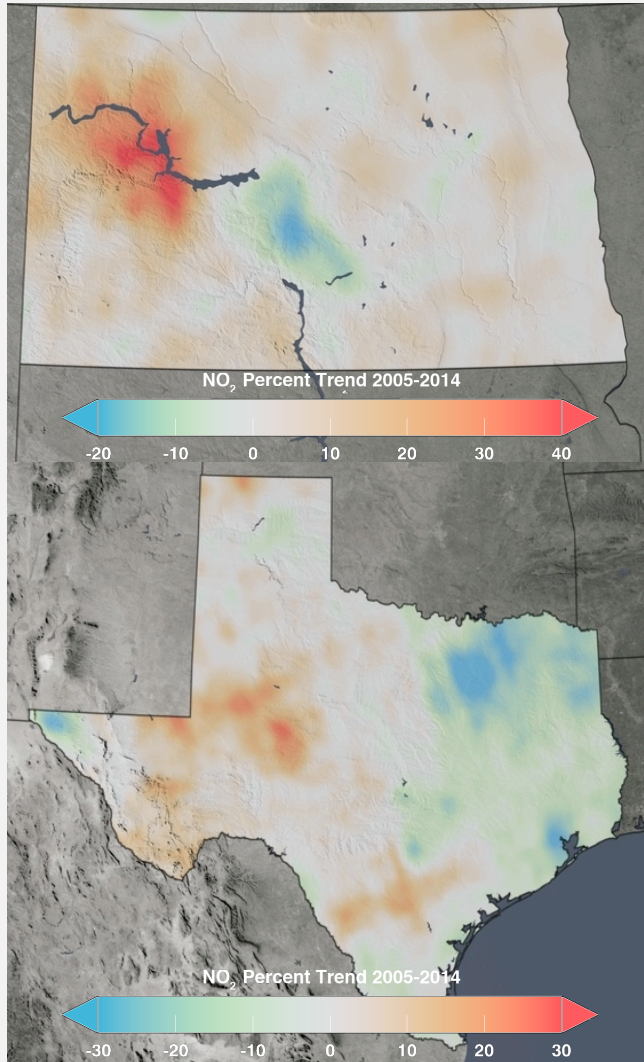


NO₂ Trends Over the United States



OMI Detects NO₂ Increases from ONG Activities

2005-2014



North
Dakota



Williston Basin

Suomi NPP VIIRS Lights at Night

Texas



Permian Basin

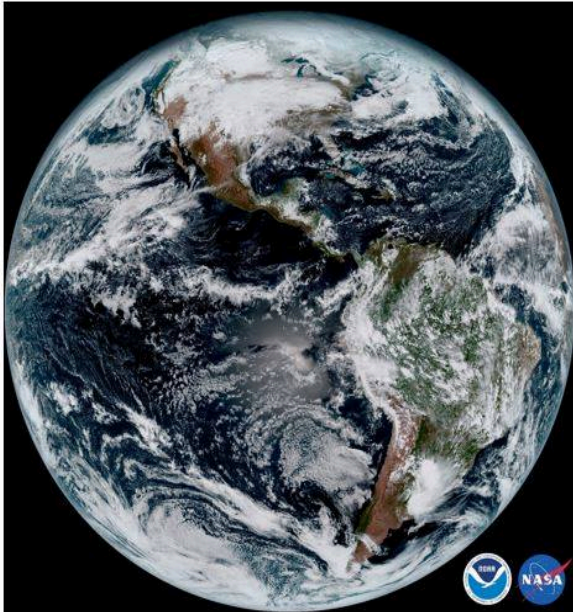
Eagle Ford

A satellite image of Earth, showing a large grey rectangular overlay in the center. The overlay contains the title text. The background image shows a mix of land and water, with some snow-capped mountains visible in the upper right.

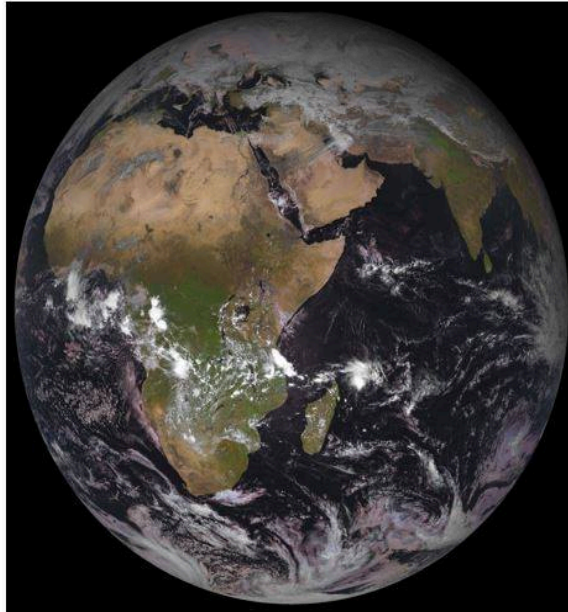
Future Satellite Capabilities for Air Quality Applications

Breaking the Temporal Barrier

The beginning of a new era in satellite remote sensing of air quality



GOES-16



METEOSAT-8



HIMAWARI-9

Source: NOAA NESDIS

GOES-R



- Launched: November, 2016
- Advance Baseline Imager (ABI): 16 Spectral Bands
- Very High Temporal Resolution: 15 min – 30 seconds

GOES-16 Loop: Smoke Over the Southeast U.S.

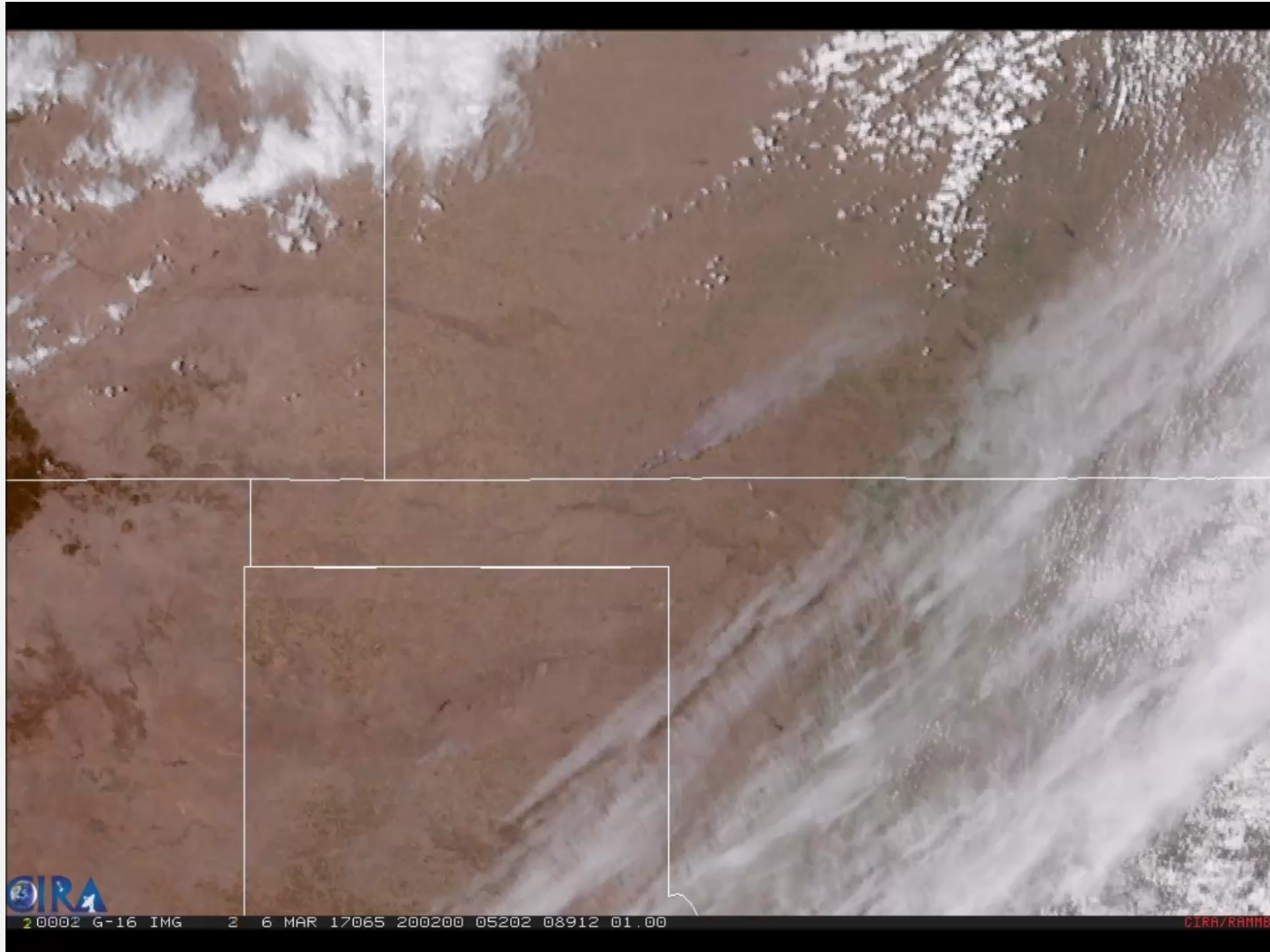


Image: NOAA CoRP, STAR: http://rammb.cira.colostate.edu/ramsdisk/online/loop_of_the_day/

HIMAWARI-8 Loop: Fog and Smog over India

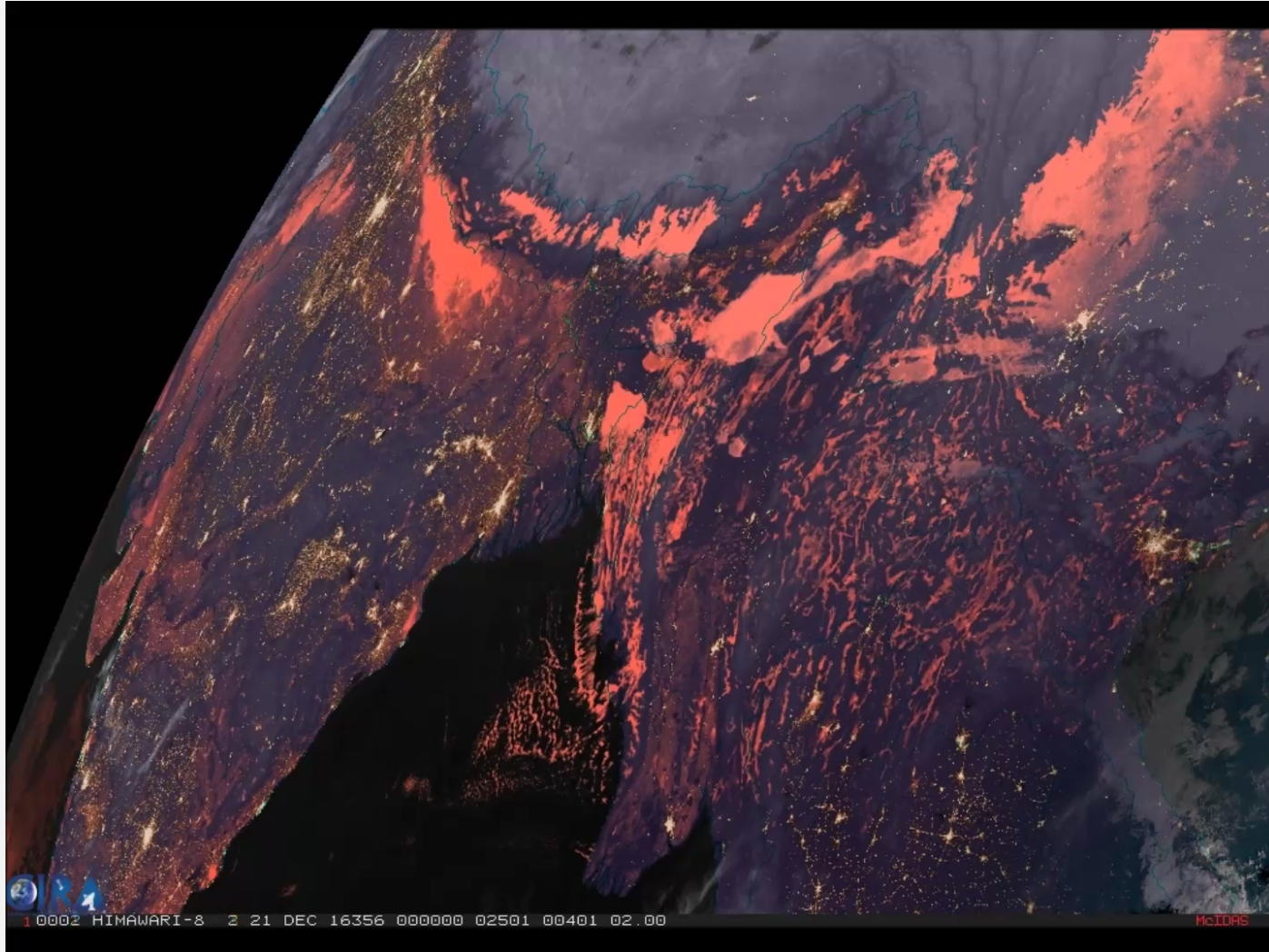


Image: NOAA CoRP, STAR: http://rammb.cira.colostate.edu/ramsdisk/online/loop_of_the_day/

TROPOMI Highlights

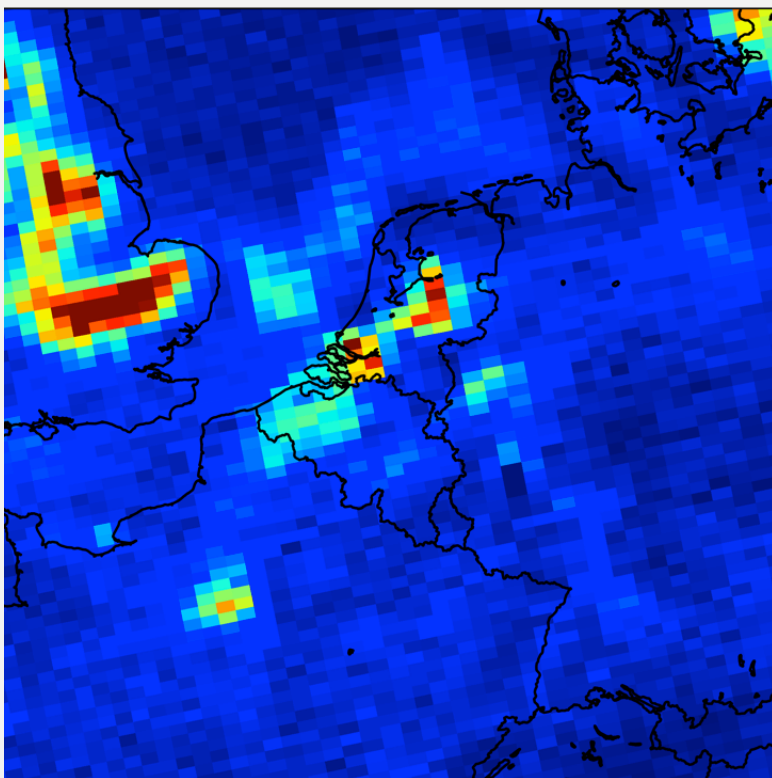
- **Launch 2017**
- Observes whole globe
- Sub-urban spatial resolution (7 km x 7 km)
- 1x/day: NO₂, ozone (0-2 km vertical), aerosol, clouds, formaldehyde, glyoxal, SO₂, CO, methane

**Measuring on Sub-Urban
Level**

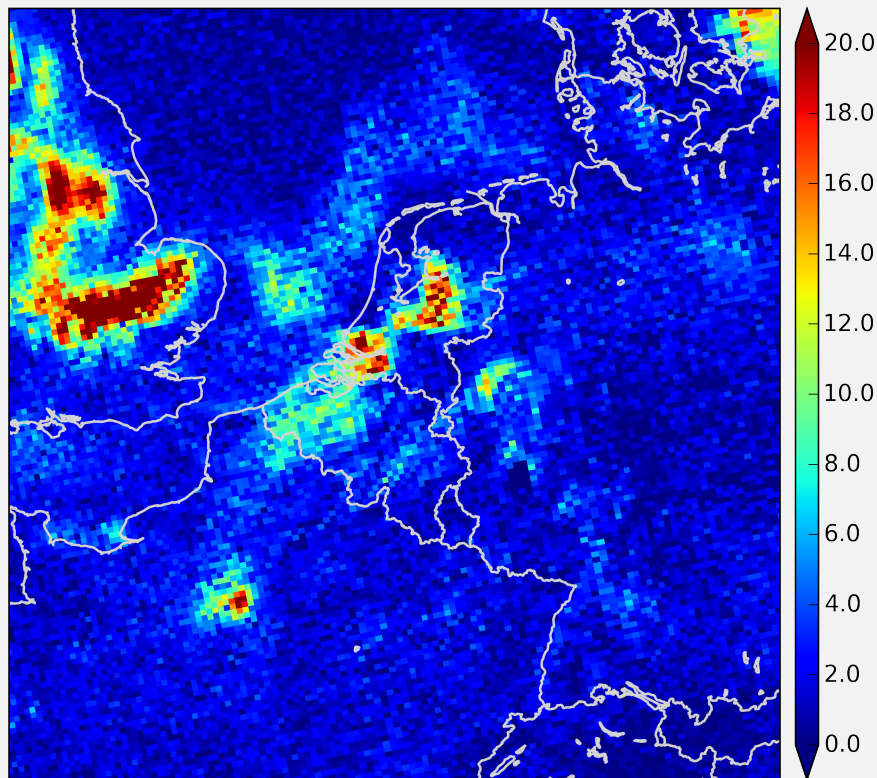


TROPOMI: Impact of Resolution

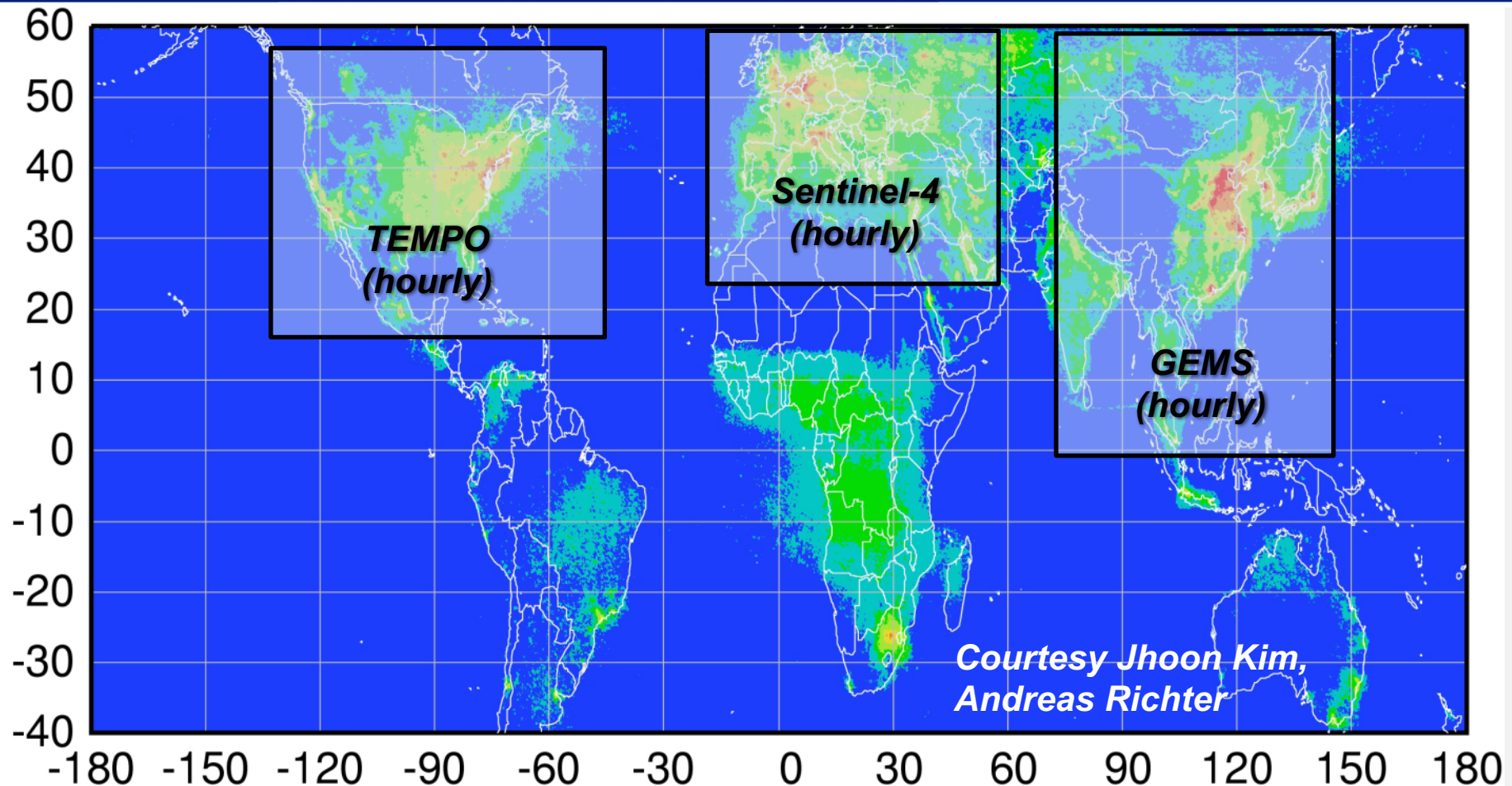
OMI (now)



TROPOMI (Simulated data)



Global pollution monitoring constellation (2018-2020)

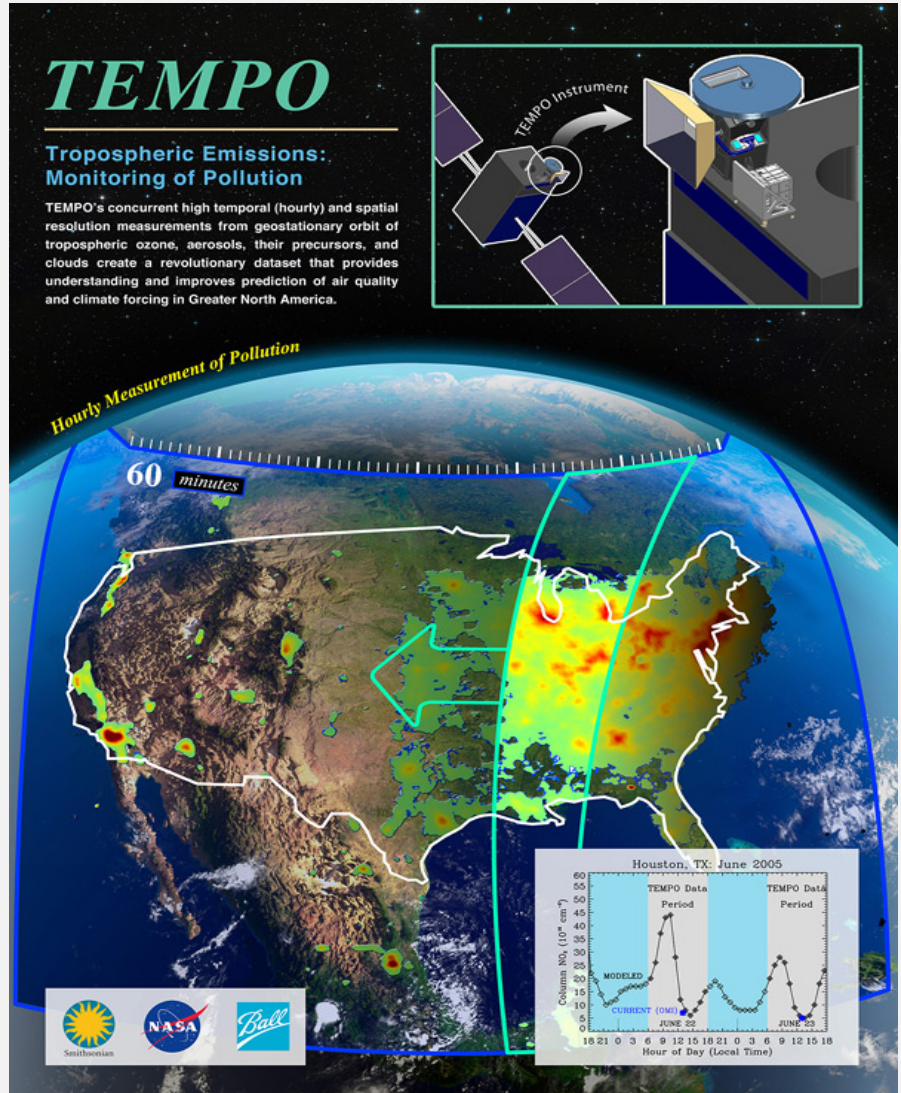


Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

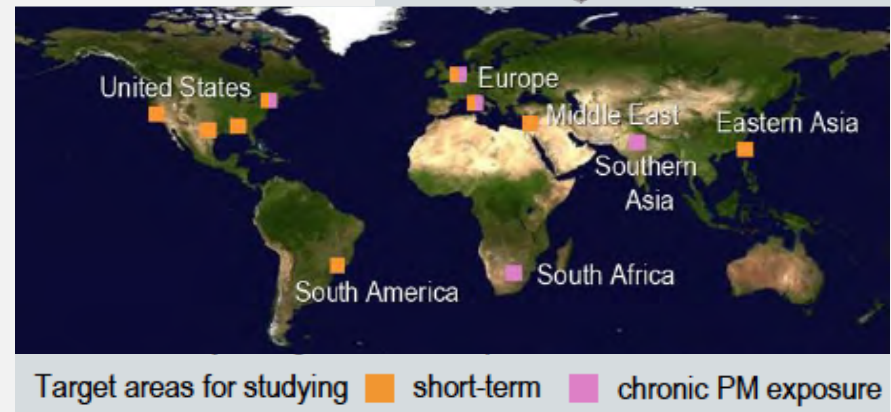
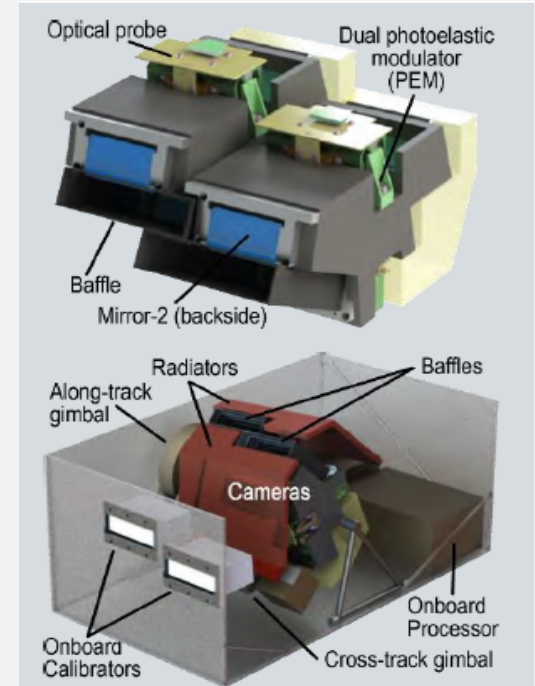
TEMPO

- Geostationary over North America
- High Temporal Resolution
– 1 hr
- High Spatial Resolution
– 2.2 x 4.7 km
- Spectral Range
– 290-740nm
- Data Products:
– O₃, NO₂, C₂H₂O₂,
aerosols, cloud
parameters, & UVB
radiation
- Expected Launch: 2021



Multi-Angle Imager for Aerosols

- Mission Goal: Assess linkages between different airborne particulate matter types and adverse birth outcomes, cardiovascular and respiratory disease, and premature deaths
- Sun synchronous orbit
- Spatial Resolution: 230 m
- Large Swath Width: 600 km
- Expected Launch: 2021



Questions & Discussion

- Can satellites help fill some of the data gaps?
- What are advantages of polar orbiting satellites as compared to geostationary satellites?

A satellite image of the North Atlantic Ocean, showing the eastern coast of North America on the left and the western coast of Europe and Africa on the right. A large, semi-transparent grey rectangular box is centered over the ocean. The word "Questions?" is written in black text in the lower-left corner of this box, with a horizontal line underneath it.

Questions?
